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Sewage Contamination of Bathing Beaches in England and Wales

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PREFACE

For some years there has been growing apprehension about the danger of bathing in sea-water polluted by sewage. Owing to the increase in the population and the greater ease of travel, the sewerage systems of many coastal towns have now to bear a far greater load than they did when they were installed perhaps fifty or more years ago. As sewage discharged into the sea is usually untreated, it follows that the amount of excretal pollution in some areas is reaching a point at which it is becoming aesthetically unpleasant, and it is not difficult to understand the fears of the public that bathing in such areas is liable to give rise to enteric fever or poliomyelitis.

In 1953 the Public Health Laboratory Service, which is directed by the Medical Research Council for the Ministry of Health, set up a research committee to investigate the medical and bacteriological aspects of sewage contamination of bathing beaches on the coasts of England and Wales, and the committee have now completed their study. The detailed findings of investigations of this kind necessarily include much technical material which must be made available for critical appraisal by other bacteriological and epidemiological workers; this is particularly true of the present study, which deals with a field in which previous epidemiological studies have been almost totally lacking. At the same time the subject is one that has aroused more public interest than most problems of hygiene, and is of special interest to local authorities. It was therefore decided to present the findings in two forms. The present memorandum is designed for the non-specialist reader; it includes brief explanations of certain technical matters, and as far as possible presents the findings of the committee in non-technical terms. The detailed technical findings, on the other hand, are published separately in the December 1959 issue of the Journal of Hygiene; medical officers, bacteriologists and others interested in the details of the committee's work will naturally refer to the article in the journal for amplification of the findings presented in this memorandum. The results of the investigation are reassuring. They should go a long way towards relieving anxiety about any presumed danger of contracting infectious diseases such as enteric fever or poliomyelitis from sea bathing.

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I. Historical Survey

The principles underlying the methods of sewage disposal adopted in this country during the past fifty years are based largely on the work of the Royal Commission on Sewage Disposal, which was appointed in 1898 and which published a notable series of reports between 1901 and 1914. The Fourth Report of the Commission dealt with sewage pollution of tidal waters, but its emphasis was almost exclusively on the hazards attending the contamination of shell-fish with enteric organisms. On the health hazard from bathing in sewage-contaminated tidal waters, the Commission merely expressed the opinion that "it does not appear that any serious injury to public health is to be feared from pollution of bathing grounds by sewage, if reasonable care is taken in selecting positions for outfalls".

A number of outfalls had been constructed before the turn of the century, and since then schemes for the construction or improvement of outfalls have been put into effect in many areas. With increasing coastal population and water consumption, however, some of the outfalls are now discharging many times the volume of sewage they used to, and, because of coastal development, some outfalls are not as well sited as they were. Some local authorities have consequently been faced with serious nuisance problems in bathing beaches in their areas.

A review of the bacteriological state of bathing waters around our coasts and of the safety of bathing in these waters was due for a number of reasons in addition to that of general public interest in the subject. Firstly, developments in bacteriological techniques have in recent years greatly increased the precision of epidemiological inquiry into the main water-borne disease that affects Britain, viz. enteric fever. Secondly, the advent of poliomyelitis as an epidemic disease during the past twelve years has caused public apprehension about the possible risk of contracting poliomyelitis through bathing in sewage-polluted coastal waters. Thirdly, it has become customary in recent years to pass judgment on the suitability for human consumption of drinking water, milk, shell-fish, ice-cream and other foods by means of bacteriological tests, and the question whether the suitability or otherwise of sea-water for bathing should not be similarly decided has not unnaturally been raised.

PREVIOUS LITERATURE ON THE HEALTH RISKS OF BATHING IN SEWAGE-POLLUTED COASTAL WATERS

As public interest centres on the possible risk to health of the discharge of sewage into the sea, it is logical to discuss first whether the Royal Commission was unduly optimistic in its opinion, quoted above, that, provided outfall sites were chosen with reasonable care, the amount of sewage pollution of bathing waters was not likely to constitute a serious public health risk. The first systematic attempt to collect information on the health risks of bathing was made by an American joint committee on bathing places, which reported in 1922 on the results of a questionnaire sent out to health officers, ear, nose and throat surgeons and eye specialists. They were asked to cite evidence of health risks attached to bathing, and to state whether in their opinion various infectious diseases could be transmitted through bathing. The findings reported can be criticized on various grounds, but it appeared that infections of the throat and upper nasal passages, including tonsillitis, sinusitis, and middle-ear infection, were reported more frequently than gastro-intestinal disease as a sequel to bathing. Taylor (1939) argued that the respiratory tract of man is ill adapted to an aquatic environment, and that in every species whose normal habitat is water, whether reptile, bird or mammal, some provision exists for excluding water from contact with the respiratory mucous membrane. Whether because of this or because a lowered resistance to upper respiratory infection attends the fall in body temperature due to bathing, an association between upper respiratory infection and bathing and diving, independent of the quality of the bathing water, is now widely accepted, and was indeed confirmed in the more recent American investigations referred to below. In the particular case of the crowded swimming pool, where close personal contact between the pool occupants may lead to direct spread of respiratory infections, the assessment of the health risks of bathing *per se* is correspondingly more difficult. In the present context, however, hazards of sea bathing that can be ascribed to the sea being an unnatural habitat are irrelevant, because the essential question is whether sea-bathing can play a part in the causation of disease through contact with or ingestion of disease-producing micro-organisms liberated into the sea through the discharge of sewage. In the remainder of this historical survey, attention will therefore be devoted mainly to such diseases.

Enteric Fever

Typhoid fever is in temperate countries by far the most serious water-borne disease. The evidence suggests that quite small numbers of typhoid bacilli are capable of causing infection; and the Croydon typhoid epidemic of 1937 is a notable example of a serious outbreak of this disease due to polluted water supplies. Typhoid fever can therefore serve as a useful, and indeed very sensitive, yardstick of the possible dangers of bathing in polluted sea-water, since the high infectivity of the typhoid bacillus and its frequent presence in sewage are both undeniable.

Only one typhoid epidemic has been ascribed to bathing in sea-water, and the circumstances in which this outbreak occurred were so unusual as to merit further description. In August, 1908, cases of typhoid fever began to occur at a Royal Marine Depot at Walmer in Kent. Nine cases had been diagnosed in no less than five separate companies between August and October, but then 17 cases occurred in E Company alone, and investigation of these by Reece (1909) suggested that 8 of them had been infected while swimming, in the course of routine training, in a swimming bath that was filled with sea-water through a 12-inch iron pipe on a rising tide and emptied periodically through the same pipe. The intake pipe was just over a hundred yards from a main sewer outfall which at the time of presumed infection received the sewage from the Marines Hospital in which the early typhoid cases in the epidemic were housed, and the incoming tidal current flowed direct from the outfall to the swimming-bath intake. Reece found a sediment of foul-smelling black particles on the bottom of the swimming-bath, and it seemed likely that the bath had contained typhoid bacilli when the group of 8 marines concerned swam there.

It may be pointed out here that the most important requirement in the discharge of sewage into the sea is that adequate dilution should take place. In the situation just quoted it is quite evident that such dilution did not occur. It is interesting, therefore, to note that the only other instances cited in the literature of an apparently significant association of typhoid with sea-bathing also happened in situations where rapid dilution of sewage could not take place. In New Haven, Connecticut, in 1921, and in New York in 1932, untreated sewage was being discharged into harbour waters, and numerous sporadic cases of typhoid fever were ascribed to bathing in these harbours. Unfortunately no satisfactory epidemiological evidence to support this was ever published, and the relationship of the typhoid cases in question to bathing remains very uncertain. There is no reason to doubt, however, that the sewage of New York contained appreciable numbers of typhoid bacilli at the time in question, as the number of typhoid carriers in New York City was reliably estimated some years after this to be about 5,000, and was probably even higher in 1932.

Apart from these records, only a few sporadic cases of either typhoid or paratyphoid fever have ever been attributed to sea-bathing, to judge by the published literature. An outbreak of paratyphoid fever that occurred in a coastal town in Britain in 1946 was thought by many local inhabitants to have been caused by sea-bathing, but, as recorded in the Annual Report of the Ministry of Health for the year ended 31st March, 1949, modern techniques later showed that the outbreak was almost certainly due to ice-cream contaminated with paratyphoid organisms and not to bathing.

Poliomyelitis

No evidence of an association between poliomyelitis and bathing in sewage-polluted river or sea-water can be found in the meagre literature on the subject.

In a paper on poliomyelitis in relation to river bathing, Boyer and Tissier (1950) reviewed a total of 767 poliomyelitis patients investigated in a period of seven years. They were struck by the rarity of a history suggesting any likelihood of infection while bathing, and could find no significant association between bathing in polluted rivers and the occurrence of this disease. The authors cite a curious episode of a rowing crew, all but one of whom bathed in a certain polluted river. The one exception did not swim for fear of contracting poliomyelitis, but he alone of the crew did in fact contract the disease.

Analysis of very widespread poliomyelitis epidemics in seaside towns might give useful information on the possible relationship between poliomyelitis and bathing. Thompson (1950) made an analysis of this kind in his study of the course of poliomyelitis in Auckland, New Zealand, where 345 cases were notified in a population of 350,000 between November 1957 and April 1959. In the early stages of this outbreak, "certain interested parties" had suggested that the incidence of poliomyelitis had been heaviest in residential areas adjacent to

Auckland's heavily populated bathing beaches, which extend for a couple of miles from near the main sewer outfall and are crowded with bathers in the summer months. Spot maps of the cases occurring in the Auckland metropolitan area showed that, on the contrary, disproportionately few cases had occurred in the residential areas concerned. To quote Thompson's words, "An unbiased observer might even say of these diagrams that it looked as if this area had been specially favoured in its avoidance by the virus."

Minor Gastro-Intestinal Illnesses

Many reports in the literature have indicated that, when drinking water supplies become polluted by sewage, gastro-enteritis and diarrhoea may ensue in many of the population concerned, without any definite evidence of infection with recognized disease-producing bacteria in the persons affected. A series of studies by the United States Public Health Service (Stevenson 1953) were undertaken in an attempt to determine whether bathing in waters of inferior bacterial quality led to an undue incidence of similar minor infections. The studies were made in three population groups, one living on the borders of Lake Michigan at Chicago, one on the Ohio river, and the third at New Rochelle and Mamaroneck on Long Island Sound, N.Y. Contact was made with the populations investigated by intensive publicity campaigns, and families who agreed to co-operate were issued with a calendar record form on which swimming experience and any minor illnesses were entered daily. Diseases recorded on the basis of a family diagnosis were ailments of the eye, ear, nose and throat, gastro-intestinal disturbances, and skin irritation.

The three studies showed that more minor illness occurred in bathers than in non-bathers irrespective of the bacterial quality of the bathing water. Gastro-intestinal disturbances accounted for only about one-fifth of the total of minor illnesses recorded. The Long Island Sound investigation was the only one of the three in which sea-water bathing was studied. In the analysis of the records obtained from this area, comparisons were made between the incidence of illness in bathers using bathing waters with less than 190, 190–430, 430–1250, and more than 1250 coliform organisms per 100 ml. (see p. 7). No significant difference in minor illness rates could be detected in bathers in waters of different quality, as shown by the bacteriological examinations of sea-water carried out during the course of the survey and correlated later with the epidemiological record of minor illness.

To obtain these largely negative results a very large volume of intensive investigation and administrative effort was required. In the Ohio river study, for instance, visits were paid to 4,238 households, of which 2,297 eventually agreed to co-operate, and attempts were made to call at least twice on all these families during the course of the study. In their report on this particular investigation, Smith and Woolsey (1952) doubted whether even on this scale conclusive evidence of the effect on swimmers of varying bacterial pollution of bathing waters was likely to emerge, while more elaborate studies might become administratively impracticable or too expensive to contemplate. In other words, the effect of the bacterial condition of the water on bathers, if it existed, was so small that to detect it would require an even larger and more carefully conducted investigation than the one just described.

The literature on the health risks of sea-water bathing, up to 1953 when the present committee was established, thus gave no serious reason for supposing that the Royal Commission's optimistic assessment of 1904 was a misguided one. Since then, a few more recent papers, such as that of Gevaudan and Tamalet (1956), have also recorded the absence of any evidence of a serious public health risk in this context.

II. Introduction to the Present Investigation

GENERAL APPROACH

It may be useful at this point to indicate our general approach to the investigations of the past six years. In the face of complaints about the pollution of coastal waters with sewage, a quantitative assessment of this pollution was clearly desirable. Extensive bacteriological surveys were therefore undertaken on many bathing beaches, to obtain information on the degree of pollution and the factors aggravating it. The surveys used both general bacteriological tests of sewage contamination and specific tests for the presence of disease-causing organisms.

As regards the determination of health risks of bathing in sewage-polluted sea-water, we considered the possibility of carrying out a similar study to that of the United States Public Health Service described above, i.e. a population study during the bathing season in which bathing habits and experience of minor illnesses were compared. Such a study was impracticable for two principal reasons: firstly by the lack of the large staff of epidemiologists required, and secondly because a large proportion of bathers at holiday resorts during the summer months are visitors from inland cities. This involved many problems, e.g. of ascertainment of their subsequent medical histories, of making contact with them in hotels and boarding houses, and of picking suitable control subjects, not to mention the difficulties posed by the other risks of seaside holidays such as those of mass catering.

The only practicable approach, and that adopted by the committee, was the retrospective one of collecting information on patients with enteric fever who might have been infected while bathing. A similar study of poliomyelitis patients was also undertaken, although doubt still exists as to whether poliomyelitis is spread primarily by droplet infection (that is in essentially the same way as respiratory diseases), or through contact with excretal matter, as with enteric fever.

TECHNICAL BACKGROUND

To make intelligible to the non-expert the later section of this memorandum in which the committee's findings are described, a preliminary technical background is provided in the following paragraphs.

The first section below deals with the basis of the most sensitive bacteriological test for sewage contamination—the coliform test. Various practical applications of this test are then discussed to exemplify its use. The succeeding section deals with the isolation of disease-producing organisms from sewage or sewage-contaminated water. This, it will be seen, is technically a difficult procedure, and is therefore far less suitable than the coliform test as an indication of sewage pollution. In the final section, some of the difficulties and fallacies in assessing the health risks of sea-bathing are pointed out.

The Coliform Test

Bacteriological detection of sewage contamination.—Escherich in Germany was the first to describe, in 1885, a rod-shaped organism present in very large numbers in human faeces and known until recently as *Bacterium coli.* This organism, which is also present in the excreta of mammals and birds, was soon found to be readily distinguished from the typhoid bacillus and other intestinal "pathogens", or disease-producing bacteria, by its ability to ferment lactose, when grown at 37°C., with the production of acid and gas in the fermentation process.

Early hopes that this organism would be a useful indicator of faecal contamination were at first disappointed by the finding of similar lactose-fermenting "coliform" bacteria in environments where no apparent faecal contamination had occurred. But the development of further biochemical tests over the years—notably by the late Sir Alexander Houston—led to the gradual recognition that one variety of coliform organism, known until recently as *Bacterium coli* Type I but now given separate generic status as *Escherichia coli,* is exclusively faecal in origin. Certain other lactose-fermenting coliform organisms are also found, usually in far smaller numbers, in faeces, but as they are rather hardier than *E. coli* they tend to survive longer in faecally contaminated environments than *E. coli* itself.

E. coli is present in enormous numbers, up to 100 million or more per gram, in fresh human and animal faeces. If, therefore, adequate cultural techniques for the laboratory demonstration of the organism are available, clearly faecal contamination of, for instance, a drinking-water supply, will be detectable up to very high dilutions. On the other hand, the numbers of disease-producing, or "pathogenic", organisms in sewage are never more than a tiny proportion of the numbers of *E. coli* present. If, therefore, we require the most sensitive index of sewage contamination, a search for, say, typhoid bacilli, will be far less effective than one for organisms of the coli group.

The coliform test in the bacteriological examination of water supplies.—The main diseases that can be contracted by drinking contaminated water—the so-called water-borne diseases—are cholera, typhoid fever and dysentery. As the causative organisms of all three are excreted through the intestine, tests for the presence of faecal contamination of water form the basis of the routine control of drinking water supplies.

To detect coliform organisms in water, all that is necessary is to incubate a sample of the water in a suitable fluid culture medium under standard conditions. If a single coliform organism is present in the sample, it multiplies rapidly in the nutrient culture medium, and after twenty-four hours the hundreds of millions of organisms resulting from this multiplication give naked-eye evidence of their presence by producing acid and bubbles of gas. If a thousand such organisms are initially present in the sample, the end-result is essentially the same. If, therefore, after inoculating, say, one millilitre of water into 10 millilitres of culture medium, we find that acid and gas are produced on incubation, all we can say is that the original one millilitre contained at least one coliform organism. The result is, in other words, not quantitative. To make it so, the bacteriologist inoculates several different volumes of the water sample being examined into a whole series of tubes—15 such tubes are used in one of the standard tests—and includes some volumes so small that in a number of them no coliform organisms will be present. From the results an estimate is obtained, by consulting appropriate statistical tables, of the numbers of coliform organisms present in 100 ml. of the sample.

When this technique fails to demonstrate coliform organisms, a negative report to this effect is given on the sample. If they are present, however, further tests are used to determine whether they are true faecal *E. coli* or not.

E. coli tends to die off in water, so that contamination in the remote past by sewage may not be revealed by this bacteriological test. This is, however, an advantage in the routine application of the coliform test, because it so happens that *E. coli* dies off at about the same rate as disease-producing bacteria like the typhoid bacillus. If it died off more rapidly, its absence would not necessarily indicate safety; if it died off more slowly danger might be indicated where it no longer existed. *E. coli* is, therefore, a satisfactory indicator organism of sewage contamination of water, although the test for *E. coli* unfortunately fails to distinguish between contamination of human and of animal origin.

Interpretation of the results of coliform tests on drinking water supplies have a qualitative and a quantitative aspect. The presence of *E. coli* in drinking water, as already mentioned, indicates faecal contamination which may have been of human or of animal origin, the former alone entailing the risk of water-borne disease when such organisms as the typhoid bacillus happen to be present in the excreta contaminating the supply. Local knowledge of the particular water supply will influence the significance placed on the finding of *E. coli.* Thus, the isolation of this organism would be of very much less concern if the water had been collected from open moorland with no human habitation for miles around than if it had been taken from a well close to a cesspool receiving sewage from a household known to include a typhoid carrier.

In the quantitative assessment of the results of coliform tests on drinking water samples, the accumulated experience of water bacteriologists over the years gives useful guidance. Thus, many natural waters from underground and stored waters from high land after purification contain no *E. coli* in 100 ml. Initially contaminated water can, moreover, be purified to this standard of quality. Finally, and most important, the epidemiological experience of many years has shown that, when sewage contamination of city water supplies occurs, even to the extent of showing coliform counts of say 20 per 100 ml. in tested samples, extensive water-borne disease often results. Hence, the current standard of acceptability for drinking water supplies for large populations, which requires the absence of faecal coli from 100 ml., although apparently idealistic, is reasonable, attainable, and necessary; but only in the context of all the relevant bacteriological and epidemiological considerations mentioned above.

The coliform test in the examination of various foodstuffs.—The value of the coliform and the *E. coli* test is restricted mainly to water for drinking purposes and to sea-water. The reason for this is that the coliform organisms present are derived very largely from human excreta, and that they tend to die out fairly rapidly. *E. coli* also tends to die out rapidly in shell-fish, and a test for *E. coli* is used in the laboratory examination of shell-fish, but the coliform test is on the other hand not reliable.

Attempts to use the coliform and the *E. coli* tests for assessing the hygienic quality of milk and foods result from disregard of the rationale of these tests.

In both milk and foods most of the coliform bacteria come not directly from human excreta but from other sources, and, unlike what happens in water, they tend to multiply, so that the numbers in which they are found by the bacteriologist may bear little relation to the extent of the original contamination.

The Isolation of Disease-Producing Agents from Sewage and from Sewage-Contaminated Waters

The source of pathogens in sewage.—When a pathogenic bacterium or virus is isolated from sewage, this is obviously evidence that the agent in question is circulating in the community from which the sewage has been derived. Its initial source in the community or its environment will vary with the biological niche occupied by the organism concerned. Poliovirus, for instance, multiplies only in the human body, if we exclude laboratory procedures and experimentally inoculated laboratory animals. Therefore poliovirus isolated from sewage must have come from the excreta of one or more human beings, who are either suffering from the clinical disease or are carriers of the virus. Organisms of the *Salmonella* group, on the other hand, discussed in greater detail below, are frequently isolated not only from human excreta, but from a wide range of animals and birds, from contaminated foods such as imported frozen egg products, and from animal feeding stuffs. The isolation of an organism of this group from sewage does not therefore necessarily indicate that overt or latent infection with the organism in question is occurring in the population from which the sewage has come.

The numbers of pathogens in sewage.—In general, the numbers of disease-producing bacteria or viruses in sewage will be very small in comparison with the numbers of *E. coli*, since only a very small proportion of the population are likely to excrete such organisms at any one time. In a recent survey carried out by the Public Health Laboratory Service, for instance, the salmonella carrier rate in children under the age of 5 years was found to be about 2 per 1,000, and that for dysentery organisms about 4 per 1,000. Kehr and Butterfield (1943) showed that, on the available published information, there was, not surprisingly, a direct relationship between the numbers of typhoid bacilli in sewage and the notified incidence of typhoid fever in the community concerned.

Notes on Some of the Different Kinds of Disease-Producing Bacteria and Viruses Found in Sewage

The Salmonella group.—This group is frequently referred to in our technical report (Report 1959), and has already been mentioned above. It now comprises more than 400 distinct species, including the typhoid bacillus and the organism of paratyphoid fever. Although these latter organisms cause a characteristic, long-continued fever with severe constitutional symptoms, the *Salmonella* group is largely associated with food poisoning. Thus, in 1958, 4,841 episodes of salmonella food poisoning, including sporadic cases, family outbreaks and more general outbreaks, were recorded in England and Wales. In about half the salmonella outbreaks that were traced to a specific item of food, processed or made-up meats were cited as the vehicles of infection.

Until recent years, salmonella food poisoning has been associated particularly with rodents and with duck eggs, but since the war attention has centred on a wide range of imported egg products and certain animal feeding stuffs which have been shown to be frequently contaminated with salmonellae, including the paratyphoid bacilli.

The different salmonellae are distinguished in the laboratory by their reactions to specific antisera. These techniques are also used in the identification of typhoid and paratyphoid bacilli, which can, however, by a further refinement of technique, be subdivided into a considerable number of sub-types—the so-called "Vi-phage types". This further sub-division is valuable in the field investigation of typhoid and paratyphoid outbreaks, since in the elucidation of an outbreak of typhoid fever due to phage Type A, for instance, a typhoid carrier who is excreting typhoid bacilli of Type A may be responsible for the outbreak, whereas an excreter of Type D organisms cannot be.

The dysentery bacilli.—As the causative organisms of bacillary dysentery are excreted in large numbers in the stools of patients with the disease, these organisms must, when the disease is occurring in a community, make their way into sewage. Unfortunately the laboratory techniques for the isolation of dysentery organisms from sewage are still very inefficient, and very little is known, therefore, of their distribution in sewage or in sewage-contaminated waters.

The intestinal viruses.—Poliovirus and certain other viruses known to proliferate in the human intestine have from time to time been isolated from sewage, by the use of specially refined techniques, particularly at times when cases of the corresponding clinical illness were occurring in the population concerned.

Technical Procedures Used for the Isolation of Pathogenic Bacteria and Viruses from Sewage

Stress is laid in a later section of this report on the need for quantitative assessment of the numbers of pathogenic organisms present in sea-water; merely to establish their presence is not enough. It is already known, of course, that they must be present in at least minimal numbers in water of many sewage-contaminated beaches, merely because they are found in the sewage. The demonstration of their presence, which has now been made, is therefore a tribute to the sensitivity of modern techniques of detection, but not necessarily more than that. If, for instance, organisms can be detected in concentration such that it would be necessary to drink hundreds of gallons of sea-water in order to imbibe a minimum infecting dose, then clearly their mere detection does not indicate danger of disease. The point has been reached where a quantitative assessment is imperative to preserve a sense of proportion. A similar situation arises in other fields of scientific work. Traces of heavy metals can be demonstrated in many foods, for instance, but it does not follow, from the existence of lead poisoning as a disease sometimes seen in man, that the merest trace of lead, detected by the most sensitive methods of analysis, makes a food unfit for human consumption.

The general principles applied to the isolation of pathogens from sewage or sea-water may be briefly described. The capacity of bacteria for multiplication in suitable nutrient fluid media has already been referred to. By largely empirical methods, media have been devised whose composition favours selectively the multiplication of the bacterium one wishes to isolate from a mixed bacterial population. Ideally, though rarely in practice, one hopes to replace a population containing, say, one typhoid bacillus to a million *E. coli* by one in which this ratio has been reversed by selective multiplication of the typhoid bacillus alone. Such methods of selective enrichment were used in isolating salmonellae from sea-water.

The viruses are incapable of independent multiplication of this kind, and will proliferate only inside the body cells of susceptible hosts or in tissue culture cells in the laboratory. The methods used to isolate viruses from sewage or water are therefore more dependent on concentration procedures, analogous to the techniques used by the chemist in isolating pure substances from mixtures. When the virus can be sufficiently concentrated, then its presence may be demonstrated by the inoculation of tissue cultures or of experimental animals. Such methods are, however, not yet as satisfactory as those used in isolating bacteria from the environment.

Some Epidemiological Considerations

The provision of an adequate background to the committee's epidemiological studies is essentially a matter of trying to answer the question: "How should one set out to establish whether bathing in sewage-polluted sea-water can cause disease that is ascribable to contact with pathogenic organisms in the polluted bathing waters concerned?".

Certain difficulties that complicate this assessment are discussed in the following paragraphs. It is useful to begin by recalling that both of the two major water-borne diseases, typhoid fever and cholera, were known to be capable of water-borne spread twenty to thirty years before the typhoid bacillus or the cholera vibrio were first described. Dr. John Snow's investigations in the London cholera epidemic of 1854 showed that the cholera mortality was six times higher in households supplied with water by the Southwark and Vauxhall Water Company, whose intake was from the heavily contaminated river Thames at Battersea Fields, than in those supplied by the Lambeth Waterworks Company, which took its water from the purer river higher up at Thames Ditton. It was this significant association of cholera incidence with water supply that led, before the organism of cholera had been discovered, to his thesis that cholera was water-borne. The clinical disease was a sufficiently definite one to permit this association to be established, just as measles statistics have been published for a very long time although the causative virus has only recently been demonstrated in the laboratory.

Finding a pathogenic organism in sea-water is thus only one element in the assessment of whether bathing causes disease. Undue emphasis on it could indeed be seriously misleading if other relevant factors in the aetiology of the disease concerned were not also borne in mind. Thus, a history of recent bathing in sea-water known to contain typhoid bacilli might offer a superficially plausible explanation of the mode of infection in a patient with typhoid fever and lead to the omission of further investigation. But if later bacteriological studies showed that the typhoid bacilli found in the sea had been excreted by, say, the patient's cook—a typhoid carrier—the danger of undue emphasis on the sea-water findings to the neglect of more direct channels of food-borne infection would at once become clear.

As mentioned above, the demonstration that typhoid fever and cholera could be water-borne rested on the establishment of significant associations. With a common summer activity like bathing, however, caution is necessary in ascribing significance to a bathing history. If, for example, an outbreak of poliomyelitis occurred in a seaside town during the bathing season, many or all of the patients might well have bathed during the previous two or three weeks. But if all the healthy children in the neighbourhood had also bathed in the same period, the bathing history of the poliomyelitis patients would thereby be discounted. A moment's thought will show that the significance of associations in everyday affairs is constantly being tested in this way. If, on the other hand, 80 per cent. of the poliomyelitis patients gave a history of bathing and only 20 per cent. of healthy children, a significant association between bathing and poliomyelitis would then have emerged—provided the figures were reliable. This, however, would still not prove that bathing caused poliomyelitis. It might be argued, for instance, that certain physical types of children were more liable to poliomyelitis and also more likely to indulge in bathing; just as some experts argue that cigarette-smoking causes cancer, and others that the type of person who enjoys smoking happens to be also the type that is susceptible to cancer.

If a statistically significant association was found between a history of sea-bathing and the onset of a given disease, the establishment of a direct causal relationship between the two would thus require further scrutiny. The demonstration of the causative pathogen in sea-water would then carry some weight, particularly if from previous knowledge the numbers present in the volume of sea-water with which a bather was likely to come into contact were thought sufficient to cause the disease.

The establishment of a significant association between sea-bathing and a given disease postulates a sufficient frequency of the disease to permit a test of this association to be made on data from patients and suitable "controls", i.e. healthy persons comparable with the patients in other essential respects. When, however, a particular patient suffering from a less common disease such as typhoid fever is known to have bathed recently, the internal evidence of the patient's own case history can be scrutinized to ascribe a greater or lesser degree of plausibility to the idea of an infection caused by bathing. Thus, infectious diseases have a known incubation period before symptoms commence, and a known exposure to heavily polluted sea-water can be discounted as a cause of typhoid fever if it is inconsistent with the known incubation period of that disease. Again, someone who has fallen out of a boat and swallowed large quantities of sea-water clearly makes a more convincing case for an infection to be ascribed to pathogens in the sea than does a child who has merely paddled on the water's edge.

The first approach, then, to the question whether sea-bathing causes a particular disease is the statistical one. This alone would be conclusive if investigation showed that no patients with the disease had bathed in the sea. Should a statistical association between the disease and a history of sea-bathing be established, the further analysis of the evidence requires bacteriological and epidemiological skills. These may indicate that the sea-bathing effect is a purely mechanical one, as discussed above in relation to respiratory infections. Or the numbers of a given pathogen in sea-water and what is known of the mode of infection, the incubation period and other features of the disease may make it probable that a given patient has contracted his disease directly from the bathing waters.

III. Results of the Present Investigation

The foregoing discussion may be briefly summarized by stating that we have in the coliform test and the confirmatory test for *E. coli* a basis for quantitatively assessing contamination due to sewage. But little information has until now been available as to whether coliform counts on sewage-polluted sea-water give a reliable indication of the presence of pathogenic organisms, or whether the coliform count can be used in assessing health risks of sea-bathing.

The bacteriological surveys undertaken by the committee, the examination of sea-water samples for pathogenic organisms and the committee's attempts to determine the effect on health of bathing on beaches in England and Wales in their present condition are discussed in the following pages.

BACTERIOLOGICAL FINDINGS

Introduction

Sea-water samples from over 40 beaches were examined by the committee during the years 1953 to 1959. In general, arrangements were made locally for systematic collection of samples of sea-water, which were sent as rapidly as possible to the nearest Public Health Laboratory and examined by previously agreed technical procedures. In addition to uniformity in methods of examination, the culture media in use in different laboratories were also standardized where necessary by issue from a central source of crucial ingredients that might show batch variation in performance, and thus vitiate comparison of the findings of different laboratories.

Statistical Presentation of Results

The technical procedure by which coliform counts are done on individual samples of water was briefly described in an earlier section. The count of coliform organisms in a given sample is estimated from mathematical tables according to the numbers of tubes inoculated with the different measured volumes of water that show evidence of the growth of coliform organisms after incubation for a standard time.

Each sample of sea-water examined is thus represented by a calculated coliform, or *E. coli*, count in the final tabulation of results. When only a single sample from a given beach is examined, and the laboratory reports that the sample gave a count of, say, 50 *E. coli* per 100 ml. of sea-water, no particular significance can be attached to this finding apart from the evidence of the test that excretal organisms were present in the sample. If at the time of sampling tidal currents were carrying sewage from the outfall away from the point from which the sample was collected, the significance of a count of 50 would be very different from that of a similar count when conditions were at their worst, and sewage was reaching the point under the influence of an on-shore wind and an incoming tide. The essential point here is that, in contrast with the reasonable presumption that a properly collected drinking water sample from a house or a town supply will give a coliform count of the same order of magnitude as one taken from any other house on the supply at the same time, sea-water samples from sewage-polluted beaches are in general not samples of a uniformly contaminated environment. Rather can the levels of pollution on a given beach be represented as a constantly changing contour map showing a peak at the sewer mouth, but with variations in the more peripheral contours according to the operation of topographical or tidal or meteorological factors.

The only practicable procedure for adequate description of sea-water pollution on a given beach is therefore the examination of a large number of samples from different sampling points. If, at the time the samples are collected, meteorological and tidal conditions are noted, a retrospective explanation of the pattern of pollution in terms of these factors may be possible when the pattern is a straightforward one.

The reduction of the results of examination of say 200–300 samples of sea-water from beach "A" into a manageable mathematical description that summarizes these findings is the next problem. Such a shorthand statement is particularly desirable if a comparison between beach "A" and another beach "B" as regards intensity of pollution is to be made.

One might reasonably propose that the "average" degree of pollution on each beach should be worked out, and the question then arises what form of average should be used. There are various arguments for and against the use of the arithmetic or the geometric mean in work of this kind; in many bacteriological studies the geometric mean is an appropriate average to use. Neither form of average was applicable to the committee's results, and that used was in fact the median count, *i.e.* the half-way figure when all the counts on samples from a given beach were listed in ascending order of magnitude.

The median presumptive coliform counts varied greatly from one beach to another, the figures ranging from one of 40 per 100 ml. at the lower end of the scale to 25,000 per 100 ml. at the upper end of the scale. The latter beach might be called the worst beach in our survey, if by "worst" we mean "with the highest average pollution". One might, however, define "worst" as "with the highest proportion of samples with more than 100,000 coliform organisms per 100 ml.", or as "with the lowest proportion of very clean samples", and a corresponding grading of the beaches studied would be a different one from that based on median counts.

The alternative definitions of "worst" concentrate, it will be seen, on the upper or the lower ranges respectively of the counts obtained on the different beaches. One method of tabulating survey results so as to give information on these extreme values is to calculate various percentile levels. The 95-percentile level, for instance, is the level of coliform count below which 95 per cent. of the counts obtained on a given beach fall.

The results of a survey on one of the beaches examined by our committee were summarized as follows:—

5-percentile	*Median*	*70-percentile*	*95-percentile*
200	2,500	4,500	13,000

This indicates that the average coliform count, expressed as the median, was 2,500 per 100 ml. Five per cent. of all the samples examined had less than 200 coliform organisms per 100 ml., and 5 per cent. of all samples had more than 13,000 per 100 ml. Further information on the upper ranges of pollution is provided by giving the 70-percentile figure, which tells us that 30 per cent. of samples had more than 4,500 coliform organisms per 100 ml.

The Main Bacteriological Findings

The main results of the coliform tests done on many thousands of samples of sea-water from a wide range of beaches around the coasts of England and Wales can now be described. As already mentioned, the coliform test is essentially a survey procedure, and this section deals therefore with the committee's findings in so far as they touch on the practicability of using the coliform test to determine the degree and the pattern, that is, the topographical distribution, of sewage contamination of different beaches. The isolation of pathogenic organisms from sea-water samples is discussed in a later section.

(i) The active participation of a considerable number of laboratories in this work enabled the committee to investigate in some detail various purely technical aspects of the coliform test. Thus, the emphasis already laid on the importance of testing adequate numbers of samples from a given beach clearly made it desirable, on grounds of both time and economy, to find the simplest possible laboratory technique for the coliform test.

Although the ideal method for the test was not found, evidence was obtained that a solid medium, Teepol agar, rather than the fluid medium used in testing drinking waters, had great possibilities and was moreover extremely cheap to prepare. After a careful initial comparison, in one of the participating laboratories, of this medium with the standard fluid medium, it was tested by ten laboratories on a total series of 727 samples of sea-water. These were examined in duplicate by the standard test and on Teepol agar. The average results were closely similar for both tests in 9 of the 10 laboratories, as judged by the median counts obtained on the series of samples examined in each laboratory. This meant in effect that if the 10 beaches investigated were compared according to the median counts obtained, the results would be very similar whether judged by the findings of the standard procedure for the coliform test on drinking waters or by the use of the solid medium. Observations were also made on the need for standardization of the ingredients of the culture media used, and these findings should prove useful to other workers in this field.

(ii) It will be recalled that the examination of waters for evidence of sewage contamination is carried out in two stages, the first giving a total count of coliform organisms, the "presumptive coliform count", and the second evidence as to how many of these coliform organisms are faecal *E. coli.* As uncontaminated sea-water contains few or no coliform organisms of any kind, the possibility arose that as a survey procedure for bathing waters the coliform test might be sufficient, thus saving the extra time and labour required in carrying out the confirmatory tests for *E. coli.*

Two series of observations formed the basis for inquiry into this point. Firstly, a series of 1,389 samples of sea-water had been examined by the committee by a relatively simple 6-tube test rather than by the more elaborate 15-tube test used later in the comparison of different beaches.

A confirmatory test for *E. coli* had however been used in addition to the presumptive coliform test. Analysis of the findings showed that although the results of the two tests were broadly similar, this was not always the case, as certain samples with high coliform counts were found to have relatively low *E. coli* counts. This occasional discrepancy between the results of the two tests would obviously be of little practical importance in the assessment of average pollution if analysis of adequate surveys on a number of beaches submitted to both tests showed that, when they were placed in order according to the median presumptive counts obtained, substitution of the median faecal counts did not materially alter the order, though of course the actual numbers would not be the same. This was investigated in due course by analysing the results of examination of 2,271 samples of sea-water from 16 beaches. The analysis showed that, on the beaches in question, the median presumptive counts did in fact grade the different beaches in virtually the same order as the median *E. coli* count, and that the coliform count alone might therefore be used as a survey procedure to determine median counts.

(iii) The limitations of "average" counts in the description of the degree of pollution on different beaches have already been mentioned. In the following table, a slightly abbreviated form of one published in our other report (Report 1959), the findings of surveys on 10 beaches are summarized by citing for each one the median coliform count and the 5- and 95-percentile counts, *i.e.* the upper limit of the best 5 per cent. of the counts obtained and the lower limit of the worst 5 per cent. respectively.

TABLE 1

Median coliform counts per 100 *ml. and* 5- *and* 95-*percentile counts obtained in surveys of ten beaches*

Beach No.	5-percentile	Median	95-percentile
1	2,000	25,000	180,000+
2	1,300	12,000	180,000+
3	<200	3,500	90,000
4	<200	3,250	180,000+
5	500	2,000	7,000
6	<200	1,300	35,000
7	200	1,300	5,000
8	90	800	16,000
9	<100	800	90,000
10	10	40	250

The order given in the table is that of diminishing median counts. A moment's scrutiny will show the difficulty of making close comparisons between the different beaches. It is clear, for instance, that beach 10 is less polluted than beach 1. But the difference between beaches 5 and 9 is far less clear-cut. The average pollution on beach 5, as indicated by the median count, was two-and-a-half times that of beach 9; but on the latter beach the worst 5 per cent. of samples were very much more polluted than the corresponding ones on beach 5, as shown by the high 95-percentile count. Naked-eye evidence of pollution on beach 9 might well, therefore, be greater than on beach 5, although the average pollution was greater on the latter beach. Comparison of the findings on beaches 6 and 7 is also very instructive in this respect. These results convinced the committee that, although the coliform test is a useful method for determining the pattern of sewage contamination on a given beach, the test cannot readily be used for the comparison of degrees of pollution on different beaches, so that a bacteriological standard for bathing beaches is impracticable for this among other reasons.

(iv) No clear relation was found between median coliform counts on different beaches and the populations of the towns served by the sewer outfalls concerned. The beach giving the highest median count was also in the group of towns with the highest populations, but considerable differences were found between the median coliform counts on beaches contaminated by the sewage of towns of similar size. This finding no doubt reflects the fact that sewage volume is only one of the factors influencing the degree of pollution of beaches, other factors being, for example, the location of outfall points and the effectiveness of tidal currents in taking the sewage away from the shore.

The Fate of Sewage Organisms in Sea-Water

The tabulated results of bacteriological surveys on sea-water samples reflect the variations in patterns of pollution due to tidal and other factors. But a further dimension must be added to this already complex picture. It has often been shown that the coliform counts obtained in sea-water surveys are considerably lower than one might have expected, on a basis of dilution alone, from the numbers reaching the sea by way of the sewage. Although the final counts actually obtained give an estimate of the bacteriological hazard to which bathers are likely to be exposed, the study of the influences that cause the rapid disappearance of sewage organisms from the sea is one of great scientific interest, although beyond the specific terms of reference of the present committee. Various workers have shown that a number of factors combine in this clearing of sea-water. The indigenous bacterial flora of the sea play some part; it is not yet certain whether they do so by using up available food supplies or by elaborating antibiotic substances to which sewage organisms are susceptible.

A detailed study of such biological aspects of sea-water bacteriology in relation to sewage disposal has not been made in the present series of investigations. The committee has confirmed, however, that, in samples of sewage-polluted sea-water stored in the laboratory, a steady fall in coliform organisms takes place, a fall that is greatly accelerated with rise in the temperature of storage. If this also occurs in the sea, one would expect to find lower counts of sewage organisms during the bathing season, and this has indeed been clearly demonstrated on one beach investigated, although the mechanism responsible has not been definitely ascertained. These findings also indicate that, when an outfall is so situated that a considerable time is required for the sewage to be carried to the beach, the bacterial contamination of the beach will be correspondingly reduced.

The Isolation of Disease-Producing Organisms from Sea-Water

Success in isolating pathogenic organisms from sea-water depends largely, as already stated, on the availability of suitable selective fluid enrichment media. Such media are available only for organisms of the *Salmonella* group, and the committee's work on pathogens has consequently been almost exclusively in this field. With certain reasonable assumptions, one can deduce from the results of isolation of salmonellae from sea-water the likely numbers of other disease-producing agents present.

The unit volume of sea-water used for salmonella isolations was three litres, or just over 5 pints. Samples of this size were filtered through thick cellulose filters which filtered off the great majority of bacteria in the sample; the filters were then cut up into four quarters which were placed each in a suitable fluid culture medium. After incubation, a search was made in these special media for organisms of the *Salmonella* group.

The available information on the numbers of salmonellae required to cause illness in man suggests that, with the exception of the typhoid bacillus, quite large numbers of these organisms, perhaps of the order of a million or more, must be swallowed before symptoms of food poisoning or enteric fever result. The isolation of salmonellae in minimal numbers from 5-pint volumes of sea-water need not, therefore, give rise to alarm, as many gallons of sea-water would require to be drunk to produce disease on this basis.

A classified list of 569 salmonella strains isolated from sea-water is published in our technical report. Essentially, these fall into three broad groups. Paratyphoid B bacilli accounted for 254 strains. A further 230 strains fell into four salmonella species well known in Britain as food-poisoning agents and the remainder were various other salmonellae isolated only infrequently.

Apart from their value in providing a basis for the assessment of health risks, the figures of salmonella isolations have been very useful in another way. When sea-water samples were collected for examination for salmonellae, a coliform count was done in addition. If the coliform counts had borne no relation to the salmonella isolations, the validity of the coliform count as a measure of sewage contamination of sea-water would have been open to serious doubt. In fact, however, a close relation was found between the two. Thus, 13·3 per cent of sea-water samples with less than 1,000 coliform organisms per 100 ml. were also salmonella-positive. This percentage increased to 29·1 when the coliform count was in the range 1,000 to 10,000 per 100 ml., and to 40·1 when the coliform count was greater than 10,000 per 100 ml. Thus the coliform counts, in general, do give a reasonable indication of the probable content of pathogens in sea-water. They might underestimate it, of course, during an extensive epidemic of, say, typhoid fever, in the community from which the contaminating sewage was derived.

Very little success was obtained in the isolation of other disease-producing agents from sea-water, probably because adequate technical procedures for the isolation of very small numbers of these organisms are not yet available.

THE HEALTH RISKS OF BATHING IN SEWAGE-POLLUTED SEA-WATER

As already mentioned, the committee tried to find out whether a significant risk of contracting enteric fever or poliomyelitis could be ascribed to bathing in sewage-polluted sea-water. The planning of these investigations and the results obtained are described in the following sections.

Poliomyelitis

As the technical methods for isolating the virus are still not sufficiently delicate to permit a topographical study of its distribution in sea-water, the investigation of this disease had perforce to be limited to an epidemiological inquiry.

If a child who develops poliomyelitis happens to have bathed in sewage-polluted sea-water a week or two before being taken ill, it is not surprising that its anxious parents should ascribe the onset of the illness to bathing. As already pointed out, one method of testing this hypothesis is to examine the recent bathing histories of a series of poliomyelitis patients and see if their bathing experience differs from that of a series of similar healthy controls.

The selection of appropriate controls for visitors to the seaside who contract poliomyelitis presents the same kinds of difficulty as planning a survey of minor infections in such visitors. It was decided, therefore, to investigate the recent bathing histories of children living permanently in seaside towns who developed poliomyelitis. Suitable controls were readily available by picking from school registers, or from local birth registers in the case of younger children, the names of those children who were of the same sex and as nearly as possible the same age as the poliomyelitis patients. Bathing histories were obtained from both patients and controls by the local medical officers of health. In all, 150 such pairs were investigated. The poliomyelitis patients included 94 paralytic and 56 non-paralytic cases; it is well known, of course, that the disease is not always accompanied by paralysis.

The analysis of results was made in two stages. The similarity of the two groups, *i.e.* patients and controls, as regards age and the socio-economic status of their families, was first confirmed by scrutiny of the record forms. The bathing histories of the two groups were then compared, and were found to be closely similar. Thus, of 94 cases of paralytic poliomyelitis, 23 had bathed during the three weeks before the onset of symptoms. Among the controls, 24 out of 94 had bathed during the same period. In the non-paralytic group, 22 out of 56 patients had bathed, and 20 of the 56 controls. When the histories were compared according to whether the children had bathed 1–3, 4–7, 8–14, or 15–21 days respectively before the onset of symptoms in the patients, no difference could again be found between patients and controls.

These findings suggest that bathing history is irrelevant in the causation of poliomyelitis, because a history of having bathed on a certain date so many days before the onset of the disease is just as likely to be given by a normal healthy child asked the same question as by the poliomyelitis patient. In addition to throwing doubt on the significance of a history of bathing, the results also bring out the fact that only about a quarter of the patients and the healthy controls had bathed at the relevant times. In the remaining three-quarters of the poliomyelitis patients, sea-bathing could therefore not be responsible for the disease as there had been none.

Enteric Fever

The incidence of enteric fever, *i.e.* of typhoid and paratyphoid fever, in England and Wales, has been so low in recent years that it would take a very long time to investigate the association of enteric fever with sea-bathing in the way that was done for poliomyelitis as described above. All notified cases of enteric fever are, however, followed up very carefully in Britain. The thoroughness of this follow-up is greatly helped by the fact that all strains of typhoid and paratyphoid B bacilli isolated in Britain are sent for phage-typing to one laboratory in London, and that the director of this laboratory is also in charge of the Enteric Reference Bureau, which sends out an inquiry form on all notified cases of enteric fever. During the past few years a specific question on bathing history has been included on this form.

The investigations of this Bureau, and of various medical officers of health, have detected each year, on average, less than one case of enteric fever in England and Wales with a history pointing to a possible sea-bathing infection.

Four of these cases of paratyphoid occurred in 1956–8. They were associated with two beaches that had been intensively studied by members of the committee. Both beaches were extremely unsatisfactory even on aesthetic grounds, and gave median presumptive coliform counts of 24,000 and 12,000 respectively per 100 ml. The beach with the higher median count was so muddy that bathing only occurred there at high tide, as walking through the mud to reach the water daunted even the hardy bathers who used this beach. Paratyphoid bacilli of the same phage types as those responsible for the illness in the four paratyphoid patients had been isolated from sea-water from the beaches concerned before the occurrence of the disease.

Although these observations strongly suggest a connection between the bathing beach and paratyphoid fever, nevertheless, in view of what has been said about the numbers of paratyphoid bacilli present in sea-water and the minimal dose of these organisms required to cause the disease, the committee think it far more likely that the four patients just referred to were infected by direct contact with undisintegrated faecal matter rather than by swallowing contaminated sea-water.

Apart from these patients, histories suggesting the possibility of a bathing infection were obtained on only two typhoid and four paratyphoid cases in the ten years 1946–56.

The incidence of typhoid and paratyphoid fever has been decreasing in this country in recent years, and the residual numbers of enteric carriers will therefore also decline. It thus seems probable that the relative numbers of enteric bacteria in sewage, and also in sea-water contaminated by sewage, will also diminish, with, in consequence, a smaller risk of contracting the disease even on the foulest beaches.

IV. General Discussion

The Assessment of Bathing-Water Pollution

Apart from beaches where sewage pollution is so gross that the crudest aesthetic arguments are sufficient in calling for improvements, the assessment of degrees of sewage contamination on bathing beaches presents a number of difficulties.

The question is often posed whether a bacteriological standard for bathing waters should not be established. If a given bathing beach failed to conform to this standard, improvements would then be insisted on, whether by prolongation of the sewer outfall or by some form of sewage treatment.

Standards for bathing waters have been used in the United States for many years, but they vary widely from one authority to another, and the standards proposed have ranged from those required for first-class drinking water supplies —*i.e.* with no faecal coli per 100 ml.—to 10,000 per 100 ml. Although allegedly based on public health considerations, no American standard has ever been supported by critical epidemiological data.

The present committee considers bacteriological standards impracticable for various reasons. The setting of a standard for any substance or product seems to us in the first place to postulate some degree of homogeneity. In this regard, the great complexity of patterns of pollution on bathing beaches would alone seem to make the establishment of a standard unrealistic. Furthermore, a standard implies comparison with an accepted norm—in this instance presumably a satisfactory beach—and as already pointed out, serious difficulties arise in comparing any two beaches. Again, if a particular limiting figure, say of median presumptive counts on a given beach, were set, the justification for the particular figure chosen would seem to us to be very difficult; and in any case judicious selection of sampling points and times would readily permit deliberate up-grading or down-grading of a given beach at will, so as to comply or fail to comply with the figure required.

We would suggest that, where information is required on the degree of pollution of a given beach, it is a waste of time to take occasional samples of sea-water and ask a laboratory for a faecal coli count. If it is already known that sewage is being discharged on to the beach concerned, the laboratory finding does not provide much further enlightenment. As already pointed out, the result obtained can certainly not be assessed in relation to the classification of drinking water supplies. The only value of bacteriological techniques would seem to be in properly planned bathing-water surveys done in collaboration with public health laboratories where the circumstances call for such a survey, as, for instance, in determining the best position for a new sewer outfall.

Effects of Sewage Treatment on the Bacterial Counts of Coastal Bathing Waters

The committee has not yet been able to make a careful study of the effect of comminution or of other modifications in sewage disposal on the bacterial quality of sea-water, and in particular on the distribution of pathogens. On some of the beaches studied, comminution—*i.e.*, the mechanical disintegration of the sewage before discharge—is practised during the bathing season. Analysis of the bacteriological results obtained before and after the start of comminution has not, however, shown any obvious effect on the topographical distribution of pollution on the beaches concerned.

Clearly, comminution may be desirable in situations where gross visible contamination of bathing beaches is occurring. Under these conditions the disintegration of faecal masses might be desirable on health grounds as well as aesthetically, because this would reduce the chances of contact with a heavy concentration of infective excreta from carriers, and would, moreover, expose the disease-producing organisms to the disinfectant action of the sea-water.

Where no gross pollution of beaches is occurring, the need for extensive improvements in the quality of sewage effluents discharged into the sea does not, in our opinion, arise. Even full treatment of sewage does not produce a pathogen-free, sterile effluent, and the committee's findings do not offer any valid grounds for attempts to render bathing waters virtually free from excretal organisms.

Health Aspects

The committee's studies suggest that, with the possible exception of a few aesthetically revolting beaches round the coasts of England and Wales, the risk to health of bathing in sewage-contaminated sea-water can, for all practical purposes, be ignored.

Some of the obvious fallacies of ascribing diseases to bathing have been indicated. Opportunities may well exist for medical officers of health in coastal areas to undertake critical studies of, for example, minor gastro-intestinal infections occurring in the summer months if local opinion is inclined to ascribe them to sea-bathing.

Pathogenic organisms isolated from sea-water are, as pointed out, an indication of infection already present in the neighbouring community. In assessing the risks to health of bathing in a given bathing area, therefore, the known local record of gastro-intestinal diseases during the summer months should be borne in mind. In particular, it would seem more profitable on public health grounds to concentrate on immediate environmental risks, such as those of food poisoning, than on the more remote risks of infection with the same food-poisoning organisms after these have passed down the sewer outfall.